LUBRICATION

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Anti-Friction Bearings

Their Lubrication and Principles of Operation

THE adaptation of the anti-friction bearing to industrial machinery has been one of the outstanding developments in the field of mechanical engineering today. It has in fact served more than ever to impress us with the importance which should be attached to friction reduction.

This matter of friction reduction is the paramount factor in economical operation of virtually any machine, for friction is indicative of wear. Furthermore, friction may be regarded as the criterion in connection with power consumption. In other words the greater the friction between any two or more wearing surfaces, the greater will be their resistance to motion with respect to one another; that is, the greater must be the amount of power expended to bring about this motion to the desired degree.

Of course the salient factor in the reduction of friction is effective lubrication, provided that mechanical conditions are scientifically correct and capable of permitting the lubricant to perform its intended function.

Where bearings are concerned the motion involved may be either sliding or rolling. The former will prevail in sleeve type bearings; that is, devices of a stationary nature designed to support rotating shafts or journals.

Friction is maintained at a minimum in such bearings by virtue of a film of oil which fills the clearance space between the shaft and bearing. This film must be maintained under comparatively constant pressure if it is to successfully prevent metal-to-metal contact due to the pressures of operation. To bring this about oil grooves are cut in the bearing metal as an insurance of equal and uniform distribution of the lubricant. This latter may be delivered by periodic hand application, by sight feed gravity devices, by ring chain or collar distributors or by mechanical pressure, all according to size, speed, pressure, load and the importance of the particular bearing in the machine as a whole.

Sleeve type bearings are ideal from the viewpoint of simplicity, economy of installation and ease of renewal. But regardless of their type or means of lubrication, they involve sliding motion.

It is the opinion of many that sliding motion will involve more potential friction than will rolling motion, contingent of course, upon the construction of the bearing, the means of lubrication and the suitability of the lubricant employed.

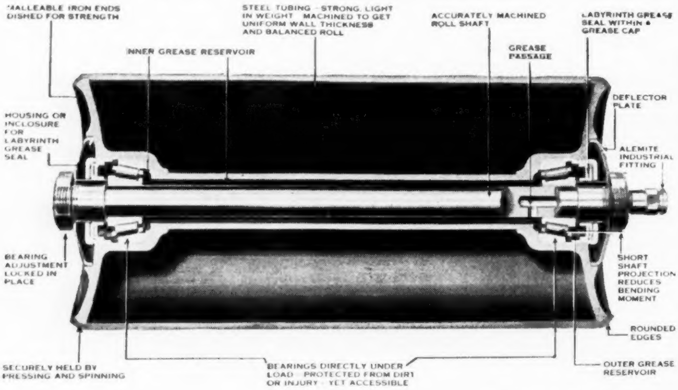
Rolling motion and the means whereby it is attained have been frequently found to be less understood by many machine operators than sliding motion. Hence, this article. It is not a brief for the ball or roller bearing. Nor is it intended as a contrast of advantages or disadvantages between such bearings and those of the sliding or sleeve type. Rather is it a discussion of the former from the viewpoints of their development, design, construction and lubrication requirements.

FACTORS INVOLVED IN DEVELOPMENT

Anti-friction bearings, as stated, are of either the ball or roller type. Their development as a means of shaft or journal support has been extensive where such requirements as positiveness in action, and maximum reduction in friction, space occupied and attention from a lubricating point of view must be observed.

Contrast of Operating Principles

The anti-friction bearing is distinctive as compared with the plain or sleeve type bearing, in that from an operating viewpoint it will be very much more independent of lubrication. In other words its ultimate efficiency will not depend to any marked degree upon its manner



Courtesy of Link-Belt Co.

Fig. 1—Details of an anti-friction belt conveyor idler roll. Note respective parts and provision for sealed lubrication.

of lubrication, for the function of the latter by means of either oil or grease is rather to protect the highly polished surfaces of the rolling elements, than to serve as a means of reducing friction, carrying journal loads or removing heat from the bearing.

In the plain or sleeve type bearing, on the other hand, regardless of the means of lubrication or the lubricant used, the ultimate speed that can be developed and the load that can be carried will depend upon how effectively the lubricating system maintains an adequate film of oil in circulation through the clearance spaces to remove frictional heat and prevent metal-to-metal contact of the sliding surfaces.

Extent of Friction Developed

The fact that the anti-friction bearing, whether it be of the ball or roller type, will normally involve a minimum of friction, will be an asset in its favor wherever the occurrence of wear may be a detriment to productive efficiency and accuracy. Rolling motion will obviously not be prone to give rise to as much wear as will sliding motion.

On the other hand, rolling motion in an anti-friction bearing must be maintained as perfectly as possible, for if it ceases in the case of any particular element as a ball or roller, more or less sliding will occur to the detriment of the contact surfaces of itself as well as the raceways. To a more or less extent this would approximate the operation of a plain bearing from the viewpoint of the type of friction developed, but with comparatively negligible means of counteracting this, for the prevailing lubricant would in all probability not be able to maintain an adequate load-bearing film or remove such frictional heat as would probably be developed.

CONSTRUCTIONAL FEATURES

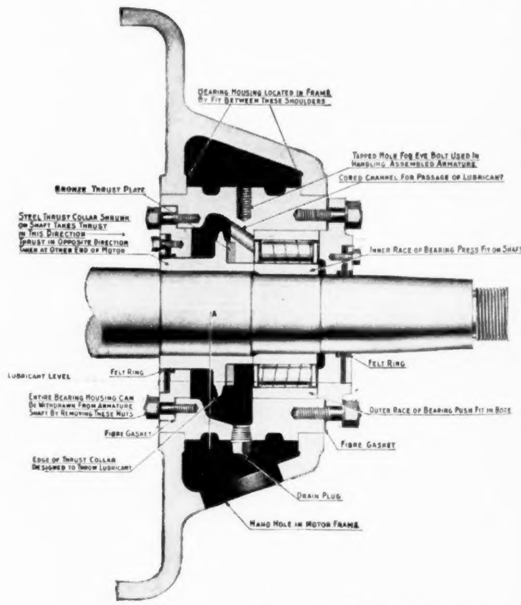
The modern anti-friction bearing will comprise a set of perfectly spherical balls or an arrangement of solid or flexible rollers.

According to the nature of these elements they may be regarded as ball or roller bearings. In a discussion of lubrication, however, the collective term "anti-friction" bearing is preferred by many.

The Factor of Design

The essential difference between any particular makes of ball bearings will be in the design of the housing.

In the roller bearing, however, the design of the roller will be the chief characteristic. In general, this will be either solid or flexible. The latter is always cylindrical in shape, the distance between the inner and outer raceways being uniform throughout the length of the roller. Solid rollers on the other hand,



Courtesy of Hyatt Roller Bearing Co.

Fig. 2—Sectional view of an electric motor equipped with flexible roller bearings.

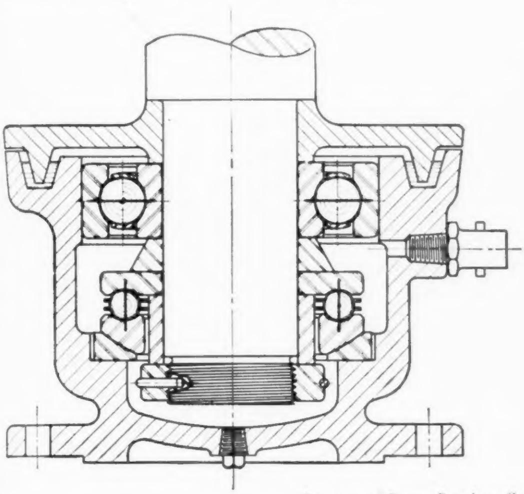
may be either cylindrical or tapered according to the type or design.

Motion Involved

As their names imply, such bearings involve rolling contact from a theoretical point of view. In the ball bearing, this rolling contact is that

of a theoretical point over a given surface. The roller bearing, however, involves theoretical line contact between the journal or shaft elements and the outer raceway.

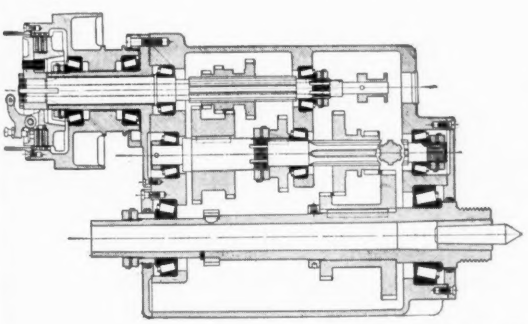
In operation, of course, this will not strictly prevail. In fact as Strom Bearings Company states in regard to ball bearings—



Courtesy of Strom Bearings Co.

Fig. 3—Radial and thrust ball bearings on a vertical shaft. Grease is used as the lubricant, a mercury seal being provided to prevent entry of foreign matter.

"The so-called point contact between balls and races exists only in theory. Actually, under load the balls contact with the races on a surface of approximately elliptical shape. The area of this surface depends largely upon the contour of the raceway and its deflection under varying loads, which again depends upon the elasticity of the materials in the balls and race rings."



Courtesy of The Timken Roller Bearing Co.

Fig. 4—A geared lathe headstock equipped with tapered roller bearings.

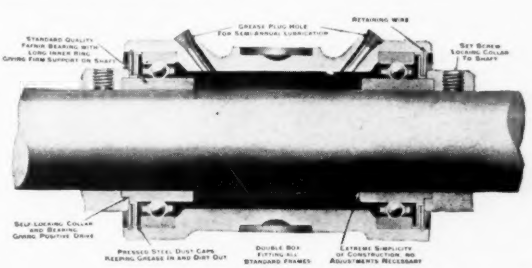
Surface or area contact may ultimately lead to sliding motion, although in the properly constructed and lubricated ball bearing the occurrence of this may often be practically negligible. In certain types of roller bearings, however, there may be more possibility of sliding motion especially where end thrust may prevail to any extent.

Speed and Temperature also Pertinent

And yet, other conditions of operation may vary far more widely. For example, take the speed of operation or the temperature. Either, in its normal variation between maximum and minimum production periods, or summer and winter temperatures may have considerably more effect upon the lubricant within an anti-friction bearing.

As The Timken Roller Bearing Company stress—"Lubricants should be selected to meet the conditions of each individual bearing application to best advantage"—being—"of proper consistency to suit the method of application and the type of closure, bearing in mind speed and temperature requirements."

Low temperatures may lead to sluggish action in certain oils, with consequent increase in power consumption. This latter, if a considerable number of bearings are involved, may become quite a factor in its cumulative effect. Hence the advisability of always choosing low pour test oils where fluid lubricants are to be used in such bearings.



Courtesy of The Fafnir Bearing Co.

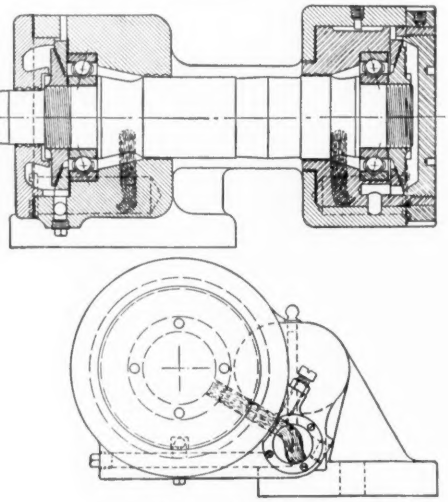
Fig. 5—Shafting equipped with grease lubricated ball bearings. Note self-locking collar and steel dust caps. The latter serve to prevent leakage of grease and entry of dust and dirt.

Operating speeds in turn will require careful consideration of the viscosity of any lubricating oil for such service. The higher the speed, for example, the lower should be the viscosity or body of the oil down to, of course, a certain definite limit, let us say, 100 seconds Saybolt at 100° F. The reason for this is that as speed of operation is increased the more rapidly will an oil in such a bearing be agitated or churned about. Such motion will be bound to lead to an increase in internal or fluid friction within the lubricant and consequently an increase in temperature. With lighter bodied oils, however, this will not be so apparent as in products of higher viscosity and less fluidity.

It is for this reason that oils of relatively low viscosity are preferred for the lubrication of high speed anti-friction bearings where installed in machine tools and certain types of textile machines.

Manner of Housing

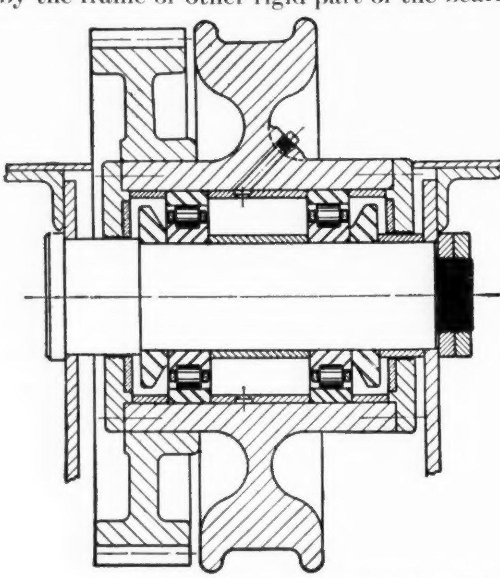
Irrespective of the nature of the rolling elements, anti-friction bearings in general will be carried or housed in much the same manner,



Courtesy of The New Departure Mfg. Co.

Fig. 6—A high speed spindle for an internal grinder equipped with ball bearings. At each end of the housing is an oil reservoir with wicks for leading oil to the tapered sections of the spindle. Rapid rotation of this latter develops an oil mist which is drawn through the bearings by the centrifugal pumping action of slingers. This amounts to circulation lubrication for the oil drains from the bearings back to the reservoirs.

i. e., in suitable containers comprising raceways or cages. In a typical design the inner race will fit on the shaft or journal, the outer being held by the frame or other rigid part of the bearing.



Courtesy of Norma-Hoffman Bearings Corp.

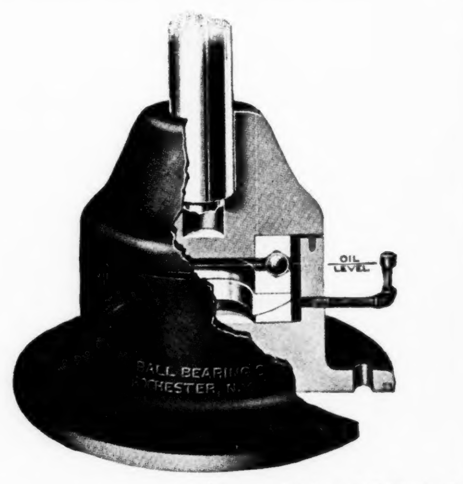
Fig. 7—Roller bearings installed on a crane wheel. Light grease or heavy oil is adaptable to these bearings.

Between these so-called raceways are located the balls or rollers. These are kept in their proper position with respect to the races and to each other by the separator, cage or retainer. Rotation of the shaft sets up a rotary motion between the rolling elements and the respective inner and outer surfaces of the raceways.

Rigidity A Factor

In view of the fact that rigidity and reduction of vibration are very essential in the operation of high speed machines designed for accurate production, it is apparent that the anti-friction bearing being practically devoid of any perceptible clearance to cause variations in shaft alignment, is a particularly adaptable device.

This very lack of clearance, however, imposes a distinct requirement upon any lubricant used in that it must be capable of developing and maintaining a film upon all contact surfaces which are in motion with respect to one another. Especially will this be essential where any sliding motion may be involved due to the occurrence of thrust pressures in certain roller bearing installations. Otherwise, wear may



Courtesy of Auburn Ball Bearing Co.

Fig. 8—A vertical shaft step bearing. Note relative location of balls and the means for maintaining the oil level.

develop to a more or less degree, particularly on starting, to result in ultimate impairment of the operating efficiency due to perhaps faulty alignment or a certain amount of play.

FUNCTION OF LUBRICATION

Mention has already been briefly made as to certain of the requirements involved in the lubrication of anti-friction bearings. In this connection it will be of decided interest to quote the S.K.F. Industries, Inc., in this regard.

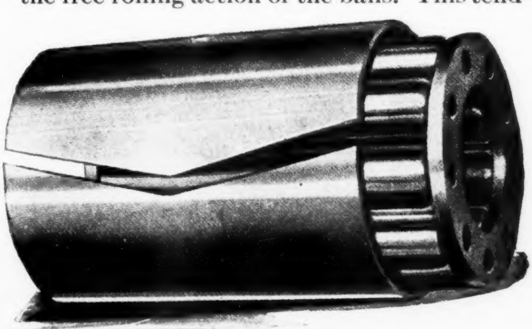
In discussing the lubrication of ball bearings in particular, they state that the functions of the lubricant should be:

"(1) To provide an oil film to lubricate the sliding contact between the balls and their retainer.

(2) To provide a protection of the highly polished surfaces of balls and races against rust and corrosion.
(3) To assist in forming a seal against the entrance of dirt and foreign matter into the bearing housing."

These requirements are very aptly amplified by The Fafnir Bearing Co., who state that they—

"Positively preclude the use of all lubricants containing acid, alkali or sulphur which, instead of protecting, would invariably pit or etch and thus seriously injure the highly polished surfaces of the balls and races. Therefore, vegetable and animal oils, which are apt to gum up, become rancid and develop acid, are not suitable for ball bearing lubrication, and should never be employed for this purpose. Moreover, lubricants containing graphite are decidedly unqualified for ball bearing use. The reason for this is that graphite is a solid substance which tends to obstruct the free rolling action of the balls. This tendency increases and eventually becomes a menace, as the oil in which the graphite is suspended is gradually lost through volatilization."

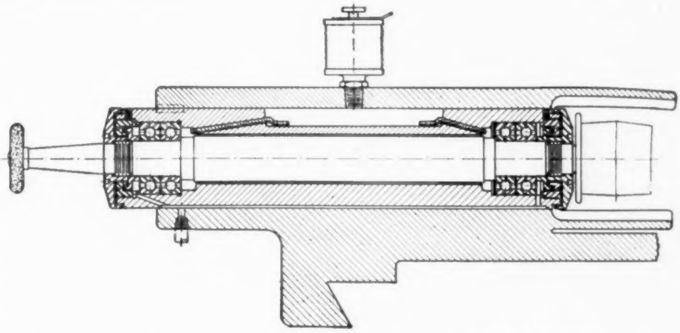


Courtesy of Royersford Foundry & Machine Co.
Fig. 9—Details of a cylindrical type of roller bearing showing housing.

To sum up: The purpose of lubrication is to facilitate as easy rolling as possible. To enable this, however, all the surfaces (which are of a highly polished nature) must be in as perfect condition as practicable.

Minimum clearance, as stated, is of course an aid to proper functioning of such bearings, for the occurrence of any play between the component parts would tend to set up a certain amount of pounding which would be detrimental to effective operation. In other words, all motion must be as nearly akin to perfect rolling as possible.

As a general rule as light a lubricant should be used as can be successfully retained in such a bearing, commensurate, of course, with the temperatures, speeds and pressures involved. Under normal conditions an oil with a viscosity of from 100 to 200 seconds Saybolt at 100° F. will be best.

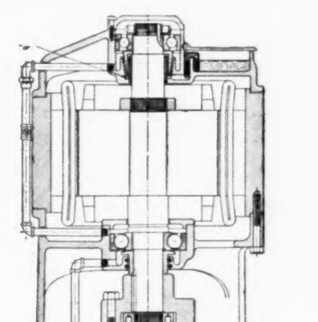


Courtesy of S.K.F. Industries, Inc.
Fig. 10—A grinding machine spindle equipped with ball bearings. This is a double bearing mounting with provision for oil lubrication.

Ball Bearings

Ball bearings are claimed to involve less possibility of friction, to a certain extent, due to the fact that there is little or no end thrust involved. As a result the lubricant in such bearings serves more nearly the purpose of acting as a seal and metal-protecting medium.

In view of this fact, and to reduce the possibility of the development of abnormal internal friction within the lubricant, it is generally advisable to pay careful attention to the oil level.

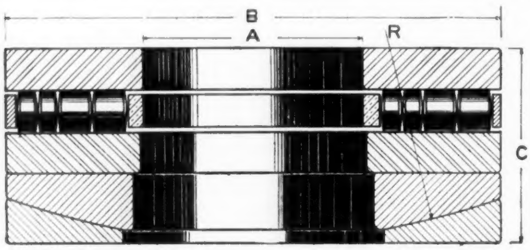


Courtesy of Marlin-Rockwell Corp.
Fig. 11—Gurney ball bearings on a vertical motor for a deep well pump head. A syphoning wick feed provides lubrication, with the advantages of one lubricating point, automatic control of rate of oil feed, automatic starting, stopping and flushing. A sight glass permits observation of oil flow. Note oil piping and connections.

As a general rule, when oil is used the housing should be filled to a level sufficient to submerge approximately half of the lower most ball. With grease however, more lubricant

must be used, the housing being from one-quarter to one-half full.

All told, it is important to remember that contrary to the principles of plain bearing lubrication, the oil in a ball or roller bearing



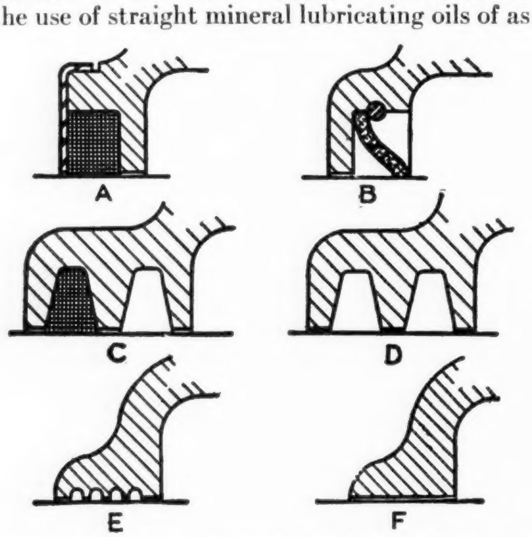
Courtesy of The Gwilliam Co.
Fig. 12—A plain roller thrust bearing combined with leveling plates.

plays but a small part as a coolant. Therefore volume is a detriment rather than an advantage.

Roller Bearing Requirements

Roller bearing lubrication by means of oil is subject to much the same conditions as stated in connection with ball bearings.

Where end thrust may develop to an appreciable extent, however, due to difficulty in keeping the rollers in alignment, or where pressures or temperatures may be high it is the opinion of certain authorities that it will be conducive to better lubrication if somewhat heavier oils are used. Under such conditions the use of straight mineral lubricating oils of as



Courtesy of Standard Steel & Bearings, Inc.
Fig. 13—Felt, leather and grease-groove anti-friction bearing seals. A is a felt ring with pressed steel retainer cap; B is a leather cup seal; C a felt and grease groove combination; D a grease-groove type; E annular grooves for grease sealing, and F the simple method of using close clearance for retention of lubricant and exclusion of dirt.

high as 750 seconds Saybolt viscosity at 100° F. are advocated. Even mineral cylinder oils of a high degree of purity may be necessary under conditions of extremely high duty, pressure or temperature.

The selection of heavier oils for roller bearing lubrication, however, should be carried out with the utmost care for it is very possible to over-estimate the conditions of operation with the result that an excess of internal friction may be developed. As a rule careful observation of bearing temperatures and cooperation with the builders and oil industry will insure satisfactory results.

Lubrication Charts

In order to facilitate selection of the proper grade of lubricant to meet any specific operating condition in an anti-friction bearing, especially from the viewpoints of speed and temperature, it is deemed advisable to reprint herewith typical lubrication charts.

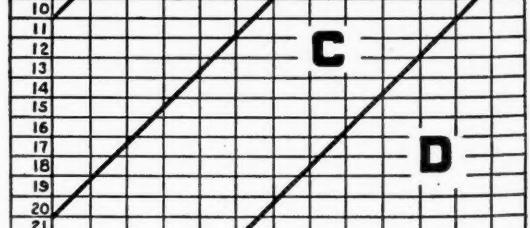
Lubrication Chart for Flexible Roller Bearings

Temp. Range	Speed R.P.M.	Nature of Lubricant Recommended	Approx. Viscosity Sec. Saybolt
Normal Temp. (30° to 125° F.)	0–300 300–1500 Over 1500	Heavy Oil Medium Heavy Oil Light Oil	140 to 160 @ 210° F. 300 to 500 @ 100° F. 120 to 220 @ 100° F.
Higher Temp. (125° to 200° F.)	0–1500 Over 1500	Heavy Oil Medium Heavy Oil	140 to 160 @ 210° F. 300 to 500 @ 100° F.
Very High Temp. (Over 200° F. not exceeding 500°F.)	At all speeds a special high temperature lubricant is required.		Steam cylinder oil is often suitable.
Low Temp. (Below 40° F.)	0–300 Over 300	Medium Heavy Oil Light Oil	300 to 500 @ 100° F. 120 to 220 @ 100° F.

Courtesy of Hyatt Roller Bearing Co.

NOTE: Heavier bodied lubricants are recommended for higher temperatures and lighter lubricants for lower temperatures in order to insure approximately the desired normal consistency at the respective operating temperatures. In this way the thinning effect of heat and the thickening effect of cold on the lubricant body are offset.

Lubricant Chart for Annular Ball Bearings



Courtesy of Standard Steel & Bearings, Inc.

Group	OPERATING TEMPERATURES		
	Below 32°	32° to 150°	150° to 200°
A	Low Temperature Oil or Low Temperature Grease	Medium Oil or No. 2 or No. 3 Grease	Heavy Oil or High Temperature Grease
B	Low Temperature Oil or Low Temperature Grease	Medium Oil or No. 2 Grease	Heavy Oil or High Temperature Grease
C	Low Temperature Oil	Light or Medium Oil or No. 1 or No. 2 Grease	Medium Oil
D	Low Temperature Oil	Extra Light or Light Oil or No. 1 Grease	Medium Oil

EXPLANATION: Bores refer to inside diameters of Annular Ball Bearings.
EXAMPLE: What specification of lubricant should be used for an electric motor running at 1800 R.P.M. using No. 310 Annular Ball Bearings, operating at 90°? Intersection of No. 10 Bore and 1800 R.P.M. lies in group "C". Therefore, correct lubricant is either light or medium oil, or No. 1 or 2 grease.

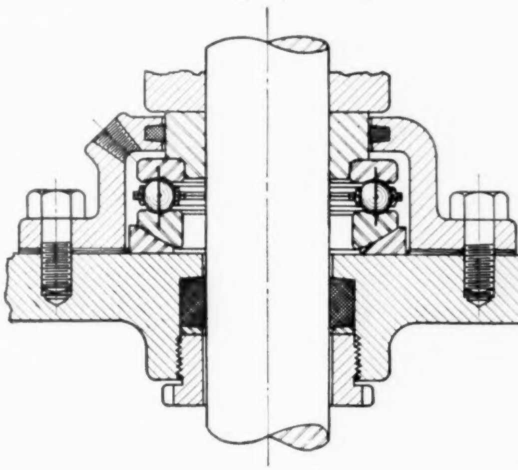
Oil	Viscosity Range	
	Saybolt at 100° F.	Saybolt at 210° F.
Extra light	75–175	36–41
Light	176–300	42–48
Medium	301–425	49–57
Heavy	426–700	58–70

In part these charts attack the problem from the same angle. Each is so unique in its arrangement, however, and so particularly applicable to a certain distinct type of bearing as to be of inestimable value in formulating an opinion as to the physical characteristics of the lubricants required. The chemical properties of all, as mentioned elsewhere, will hold true regardless of bearing design and construction.

Grease as a Lubricant

Wherever there is possibility of oil leakage, or under conditions of dust, dirt or dampness it may be advisable to resort to grease as the lubricant.

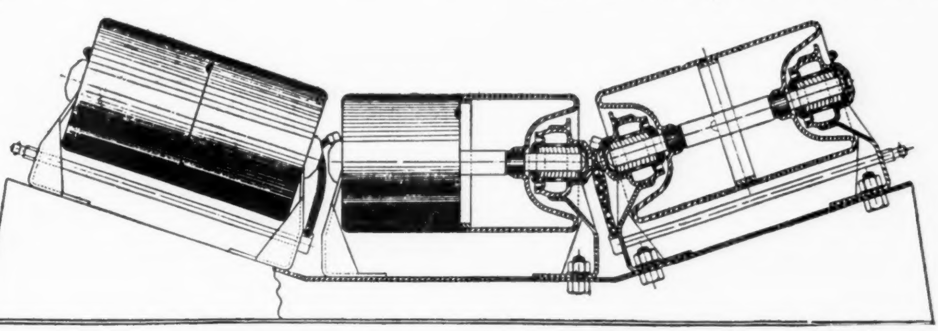
Greases furnish better seals against the entry of dust, dirt and moisture, thereby serving to protect the polished surfaces of the bearing elements in a very satisfactory manner. Grease also can be very much more effectively retained in a non-oil-tight housing; on the other hand, dirt or grit that finds its way into a grease lubricated bearing has no means of settling out, but is always held in suspension, being carried back into the bearing repeatedly.



Courtesy of Strom Bearings Co.
Fig. 15—A typical thrust ball bearing showing use of stuffing box and felt packed grooves to prevent escape of lubricant and entry of foreign matter.

To most effectively meet the requirements involved, a grease for anti-friction bearing service should:

1. Show no tendency to separate in storage or when inactive within a bearing. Nor should this occur under moderate heating.
2. There must be no tendency towards hardening or decomposition.
3. There should be no constituent contained therein which might lead to corrosion, pitting or rusting of bearing elements. As a result this would prohibit usage or accidental entry of sand, resin, salts or abrasives of any nature whatsoever.

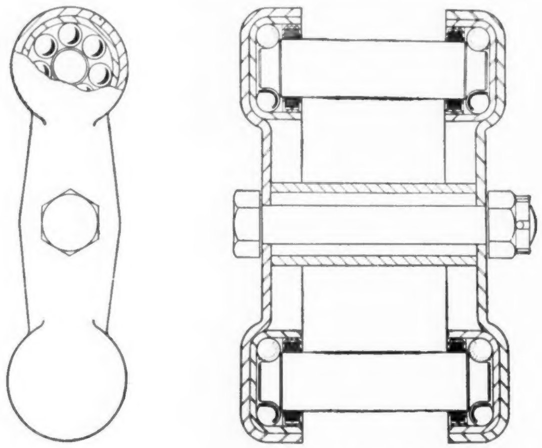


Courtesy of Hyatt Roller Bearing Co.
Fig. 14—A three-pulley conveyor idler equipped with flexible roller bearings.

4. Nor should there be any component which might tend to cause the lubricating film to become sticky or the grease itself to gum.
5. And finally, the consistency involved

should be suited to the operating requirements.

As a general rule, greases which are comparatively fluid in consistency will meet average operating conditions where the lubricant must readily cover the entire surfaces of the balls or rollers and not tend to channel in the housings



Courtesy of The Fafnir Bearing Co.
Fig. 16—Details of a ball bearing spring shackle for automotive equipment. A suitable felt packing prevents leakage of grease and entry of foreign matter.

or raceways, as might occur with more viscous products of this nature which would have less of a penetrative ability.

On the other hand, under conditions of high temperature, as, for example, in the case of certain steel or cement mill bearings, it might be necessary to resort to greases of greater body to withstand the thinning-out effects of heat, and prevent the consequent entry of dust or dirt.

APPLICATION OF LUBRICANTS

Relative to the application of grease it is interesting to note that in the case of ball bearings, according to S.K.F. Industries, Inc.,

> "A frequent cause of difficulty in the use of grease by those inexperienced with ball bearings is forcing an excessive amount of lubricant into the housing by means of a compression cup or other device. This leads to heating and often results in melting and breaking down of the grease, so that its lubricating value is destroyed. As a result, further heating takes place and the operator attempts to remedy this by the addition of more grease, thus aggravating still further the cause of the trouble. In such cases the oily or lubricating constituent will leak out from the housing, leaving the bearing entirely caked with the hard filler having no lubricating value whatever."

Care should be observed in the introduction of any lubricant into an anti-friction bearing to avoid addition of an excess of the former, and the possibility of leakage or forcing of the lubricant out past the seals.

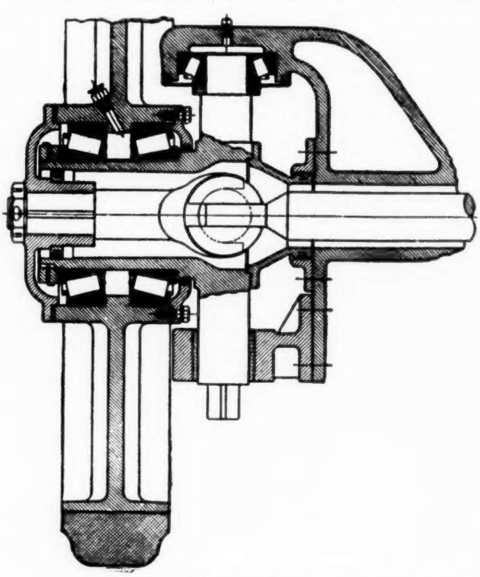
With oil over-lubrication can be more readily avoided due to the fact that oil will find its own level, which can be controlled by means of over-flow ports, a condition that can only be attained with the lighter grades of liquid grease. This is impossible with heavier products.

In a properly designed ball or roller bearing replenishment of lubricant will be necessary but once every three or four months, or oftentimes at less frequent intervals if the housing is capable of holding a relatively large volume and an effective seal is maintained.

MACHINE TOOL DEVELOPMENTS

The application of anti-friction bearings to the machine tool industry has been brought out in detail by Runge,* in his recent paper before the A.S.M.E. In particular are his observations relative to lubrication and choice of lubricants a pertinent topic. They are based on years of experience and the most detailed investigation. His primary requisite, of course, is that the lubricant be "free from acid and foreign matter."

Essentially he favors fluid oils for the lubrication of such bearings in view of the fact that



Courtesy of The Timken Roller Bearing Co.
Fig. 17—Sectional view of a steering drive wheel showing application of tapered roller bearings.

"due to the great variety of viscosities of grease, and also the numerous fillers which are used, grease lubrication is subject to a wider range of variation than is oil and is therefore less controllable."

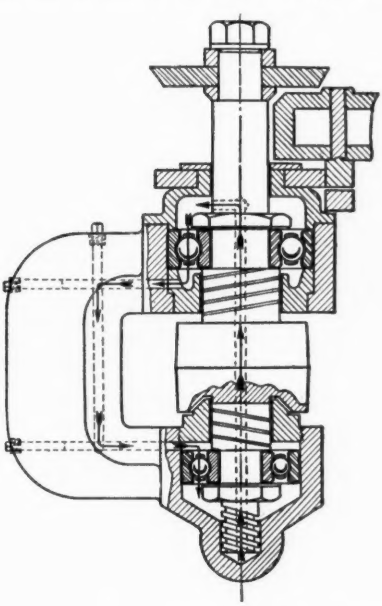
*R. F. Runge, Vice Pres., S.K.F. Industries, Inc., on "Recent Developments in the Application of Anti-Friction Bearings to Machine Tools."

An added factor is the extent to which heat may be developed through internal friction within the lubricant. Over-heating of bearings, especially on precision machinery may materially affect the accuracy of cutting and production.

The Use of Wick Filters

The investigations as brought out by this paper indicate a most satisfactory means of lubrication by the use of a wick filter oiler as illustrated by Fig. 20:

"The oil is fed through the wick as a filter and from there through the spacer ring A. Part of the oil may find its way into the bearing through capillary action along the internal surface of the spacer ring A, but most of the oil will drop on to the spacer ring B, the result of which is that most of the oil entering the housing is atomized. A reservoir is not permitted to form, as the oil will feed through the bearings and out through drain holes C. This really develops into a drop feed from oil reservoir D, as the feed through the wick is easily controlled. This has an additional advantage in that should any foreign matter or abrasive find its way into the bearing housing, there is a tendency for the oil to carry it out through the drain



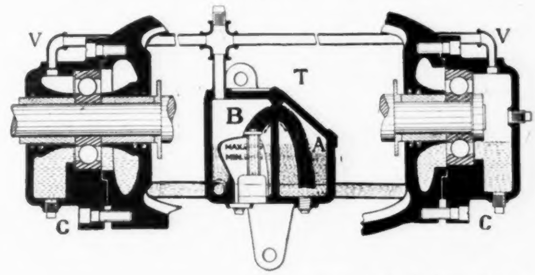
Courtesy of The New Departure Mfg. Co.

Fig. 18—A vertical cutter spindle equipped with ball bearings and an oil circulating system. Note the screw pump in an oil reservoir in the base. Arrows indicate flow of oil. At no time are the bearings so immersed in oil as to cause heat due to churning.

holes. In certain instances where capillary feed is advisable, the wick is permitted to rub on a rotating part, which not only acts as a wiper for additional oil suction, but also for atomizing.

Where automatic lubrication, or a centralized system, is used for all of the bearings on a given machine, this same principle of lubrication can be applied.

From the standpoint of foreign matter



Courtesy of L. J. Wing Mfg. Co.

Fig. 19—Section of the bearing housing of a turbine blower equipped with ball bearings. A and B are two separate oil compartments connected by a set of wicks which replenish oil in B. The bearings themselves act as oil rings. At V are shown the vent pipes.

getting into the bearing housing, the design of enclosures is of equal importance. In the design in question, at the three positions E is shown what is termed a labyrinth seal. This may be of the single or multiple type. Those shown in Fig. 20 are single, whereas those shown in the design in Fig. 10 are multiple."

FLUSHING AND CLEANING OF BEARINGS

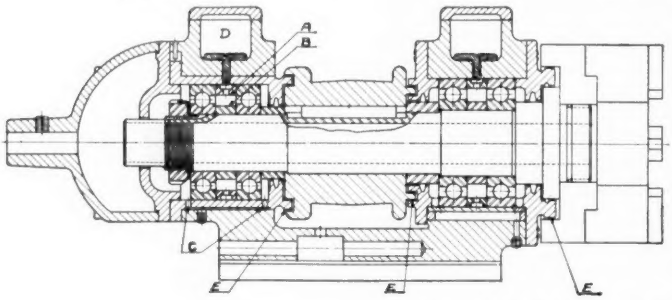
In order to insure the maximum of protection with any anti-friction bearing lubricant it is absolutely essential to keep the lubricating system as free from foreign matter as is consistently possible, according to the operating conditions and bearing construction.

There is always possibility of entrance of impurities, especially where the bearing is not properly sealed. It is a matter of decided importance for we can realize that continued churning of abrasive foreign matter with oil or grease, or in intimate contact with highly polished balls, rollers and raceways, may ultimately prove the ruination of the shaft bearing and its respective elements.

In view of the fact that it is not always possible to effect the requisite degree of sealing or to depend upon the seal being in good working order at all times, lubricating systems should be flushed and cleaned at periodic intervals. The frequency will, of course, depend upon the design of the bearing, the type of seal, the lubricant used and the extent to which dust and dirt are present.

With ball or roller bearings, once or twice a year will usually be sufficient, unless operating conditions are especially dirty. On the other hand, such bearings are quite delicate from the viewpoint of construction, and therefore oil or grease should not be allowed to become

as contaminated as is permissible with other types of bearings. Wherever grease lubricated ball or roller bearings are involved, the grease should be wiped out thoroughly at the period of cleaning; flushing is generally not an entirely satisfactory procedure.



Courtesy of S.K.F. Industries, Inc.

Fig. 20—Ball bearings installed in the work-head spindle of a grinding machine. See explanation in text, p. 129.

The instructions for flushing a bearing housing and lubricating system as stated for Hyatt Roller Bearings* on electric motors are so complete that they are stated in full below:

"It is advisable about once a year to clean out of the housing any accumulated grit or particles of metal, and to dissolve any gummed oil, since the effect of this foreign matter upon the rate of wear of the bearing is cumulative. The simplest way in which the housing can be cleaned out is to remove the top and bottom plugs, from the housing, and drain out the lubricant. Then replace the bottom plug and pour kerosene or gasoline, or a light lubricating oil heated to about 200 deg. F. into the top hole until it appears at the oil filler hole level. All plugs should then be replaced and the motor turned over slowly by hand a few times to distribute the solvent. After about ten minutes the kerosene can be drained out and the motor turned over slowly by hand with all of the plugs removed so that most of the solvent is removed. The bottom plug should then be replaced and about a half pint of clean oil poured into the housing and the motor given a few turns to distribute it. This oil will remove most of the kerosene which might otherwise have a harmful effect on the lubricating qualities of the new supply of oil.

When this small quantity of oil has been removed, and the bottom plug replaced, the housing is ready to be filled up to the proper oil level, and operation resumed."

While the use of kerosene or gasoline as a cleansing fluid is mentioned above, it is well to remember as Strom Bearings Company point out that such products may have a tendency to dilute the fresh lubricant if bearing construction is such that they cannot be thoroughly drained after usage.

Automotive Engine Cooling and Anti-Freezing Solutions

The advent of cold weather is always sure to bring up that ever-pertinent problem of automotive engine and radiator protection. It is a problem to many, involving as it does, the maintenance of adequate engine cooling with the least possibility of freezing in the cooling solution. Essentially it is simply a matter of choice of an effective anti-freezing solution and the use of this latter in sufficiently concentrated form to insure against freezing in any part of the system however long the engine may remain idle. But what to use, or how much of it, is the problem.

Consequences to guard against

Broadly speaking, lack of consideration in this regard may result in freezing. Freezing alone might be comparatively negligible were it not for the subsequent effects which it might cause. For example, leakage might result in the radiator, the cylinder block might be cracked, or the water pump put out of commission. All on account of the extent to which water or any aqueous solution expands when it is allowed to freeze or solidify.

ANTI-FREEZING SOLUTIONS

It is therefore necessary to lower the freezing point of the solution in the radiator of any motor vehicle, below the probable lowest atmospheric temperature likely to be encountered in cold weather operation. To bring this about the water must be mixed with a certain amount of alcohol, glycerine, ethylene glycol, alcohol plus glycerine, dissolved salts; or, a low viscosity straight mineral oil can be substituted for such water mixtures. This latter, however, is more strictly applicable to the heavy duty tractor, its adaptability to the cooling system

* By W. B. Wachtler formerly of the Industry Division, Hyatt Roller Bearing Co. In a paper which appeared in the Iron and Steel Engineer, May 1924.

of the average pleasure car or commercial vehicle being as yet unproven.

Desirable Properties

Regardless of the nature of the anti-freezing compound, the ideal solution should have certain definite properties:

1. The ingredients used should be easily obtainable in operating localities.
2. The possibility of freezing should be negligible.
3. It should not be injurious to either the engine or the radiator through corrosion or electrolytic action, or to rubber hose connections.
4. It should not lose its non-freezing and non-congealing properties after continued use.
5. The possibility of fire hazard should be minimum.
6. The boiling point of the solution should not differ materially from that of water.
7. The viscosity should be as constant as possible through the entire temperature range involved and the solution should remain perfectly fluid and not tend to stop up any small openings in the system.
8. It should be able to conduct heat away as rapidly as possible.

The following table will be of decided interest in this regard. It shows the freezing points and specific gravities of certain anti-freezing solutions. It is based on data developed by the Bureau of Standards.

How to use this data

Assuming that alcohol is to be employed a typical example of how to use this table, where the lowest temperature anticipated is 19° above zero Fahr. is as follows:

**If the radiator holds 3.5 gallons, 20% of this must be alcohol and the remaining 80% water. 20% of 3.5 gallons is 0.7 gal. or a little more than 5.5 pints which is the quantity required. This should be added to enough water to make 3.5 gallons; that is, the water used will be 3.5 gallons less 0.7 gal. or 2.8 gallons, a little more than 11 quarts.

DISCUSSION OF PRODUCTS

Alcohol-Water

Alcohol-water anti-freezing mixtures have probably been most commonly used by the motorist to date, owing to the fact that alcohol is easily obtainable at reasonable cost. The grade used may be either denatured or wood alcohol.

Alcohol solutions do not have any greater tendency to corrode the metallic parts of the system than water alone. On the other hand wood alcohol will often contain free acetic acid. It is advisable as a result not to use wood alcohol unless it is definitely known to be acid free. The amount of alcohol used will affect the freezing point of the mixture, as is shown in the accompanying table.

Where using alcohol it is important to remember that this product will evaporate far more rapidly than water. As a result, a certain amount must be added as make-up from time to time to keep the concentration of the mix-

**"Anti-Freezing Solutions," Journal of the Society of Automotive Engineers, Nov., 1921.

Table Giving the Freezing Points and Specific Gravities of Certain Anti-Freezing Solutions

Solution	Percentage (by volume) in water, and freezing points.				
	10% °C °F	20% °C °F	30% °C °F	40% °C °F	50% °C °F
Denatured Alcohol (90% by vol.)	—3 +27 (0.988)	—7 +19 (0.978)	—12 +10 (0.968)	—19 —2 (0.957)	—28 —18 (0.943)
Wood Alcohol (97% by vol.)	—5 +23 (0.987)	—12 +10 (0.975)	—19 —2 (0.963)	—29 —20 (0.952)	—40 —40 (0.937)
Distilled Glycerine (95% by wt.)	—2 +29 (1.029)	—6 +21 (1.057)	—11 +12 (1.085)	—18 0 (1.112)	—26 —15 (1.140)
Ethylene Glycol (95% by wt.)	—3 +26 (1.016)	—9 +16 (1.031)	—16 +3 (1.045)	—24 —11 (1.058)	—35 —31 (1.070)

ture as desired. For this reason it is well to test the specific gravity of the alcohol mixture regularly with a hydrometer calibrated for temperature correction, and check the reading with the above table.

Alcohol, however, lowers the boiling point of water to quite an extent if used in large amounts. Consequently it may frequently happen that on a comparatively warm day when the engine is "idled" the solution will boil readily and abnormal evaporation will take place, thus raising the freezing point of the remaining mixture.

Glycerine and Ethylene Glycol

Glycerine, and ethylene glycol in contrast to alcohol, raise the boiling point of water slightly, and thus they neutralize to some extent the effects of alcohol in this regard.

Glycerine, however, is claimed to be somewhat more injurious to the rubber connections which are used between the radiator and engine. An ethylene glycol or a glycerine-water mixture does not evaporate as does an alcohol mixture, so the cost and amount of ingredients used in renewing the solution will depend only on the amount to be replaced due to leaks or mechanical losses.

Saline Solutions

Saline solutions can also be used as anti-freezing mixtures in case alcohol, glycerine or ethylene glycol are unobtainable. They are made by dissolving common table salt or more frequently calcium or magnesium chloride in water.

The principal advantage of such compounds is that they are non-volatile. On the other hand the use of such salts is never advisable except in an emergency, due to the possibility of troublesome consequences on account of their tendency to attack the metallic parts of the system, especially if there is any solder or aluminum in the latter.

Mineral Oils

Kerosene or light lubricating oil may also be used as a cooling liquid. Opinion differs as to their value for this purpose. There are many instances of motor vehicles where kerosene or winter black oil have been successfully substituted for a water solution in winter service. As yet there is not enough data to warrant definite conclusions as to their efficiency.

Kerosene has a higher boiling point and a lower freezing point than water. Due to the fact that it has a comparatively high boiling point and a low specific heat, it is advantageous to use in cold weather, because it enables the engine to heat up more rapidly upon starting. Such oils in general, however, have an injurious effect on rubber connections.

WHAT TO DO IN CASE OF FREEZING

In event of freezing of the water or cooling solution at any time either through carelessness or sudden abnormal temperature drop, never try to thaw it out by running the engine. If possible, the garage should be heated or the car should be towed to a warm place. If this is impracticable it may be possible to thaw out the system by applying towels or rags wrung out in boiling water to as much of the cooling area as possible, though observing every care that no water drips upon any part of the ignition system.

RADIATOR PROTECTION AND TEMPERATURE CONTROL

While it is most essential that the liquid in the cooling system be kept from freezing, it is also important that its temperature be controlled at least to some extent in order to enable the engine to operate at its best.

Radiator Covers

Where radiator covers are used they have three distinct advantages that should be remembered:

1. They keep the engine and radiator warm.
2. They make starting easier, and
3. They save the storage battery to a marked extent.

The Thermostat

As an aid to regulation of the temperature of the cooling water with increase in thermal efficiency and reduced carbon deposits, the thermostat is a valuable adjunct in a cooling system.

This device prevents free circulation of the cooling water through the cylinder cooling jackets until the temperature of the walls has reached the desired temperature for which the thermostat is set. Thus the walls and the cylinder head can be kept at a sufficiently high temperature to aid in the complete vaporization and burning of the gasoline.

Automatic Radiator Shutters

Automatic radiator shutters are also used to serve this same purpose. These have the added advantage in maintaining a relatively uniform temperature in the air passing to the carburetor.

With a thermostatic control it is obvious that in certain instances the water passage might be so reduced that the air passing under the hood to the carburetor would take up relatively little heat, hence the temperature of the mixture might suffer a decided drop.

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